FORD, BACON & DAVIS
A Limited Liability Company

AIChE
The Global Home of Chemical Engineers

Equipment
Heat Loss

Objectives

- Review Examples Of Process Heat Transfer To Equipment Not Classified As Heat Exchangers (Fired Or Non-fired)
- Look At Ways To **Input** Heat To Equipment For Process Heat Transfer
- Identify Heat Transfer **Formulas** For Equipment Process Heat Transfer

Temperature Maintenance

- **Prevent Condensing (Gas/Vapor Service)**
  - Condensed Liquid May Cause Corrosion
  - Condensed Liquid May Create Downstream Operating Problems
- **Prevent Solidification (Liquid Service)**
  - Prevent Mechanical Damage To Pipe And Equipment Due To Freezing (Water Services)
  - Maintain Liquid State To Ensure Hydraulic Transfer
- **Viscosity Control**

Process Heat Transfer

- **Heat Transfer To Change**
  - Fluid Temperature
  - Fluid State (Phase Change)
  - Fluid Properties
- **Heat Transfer To Process (Heating)**
- **Heat Transfer From Process (Cooling)**

Equipment
Heat Loss

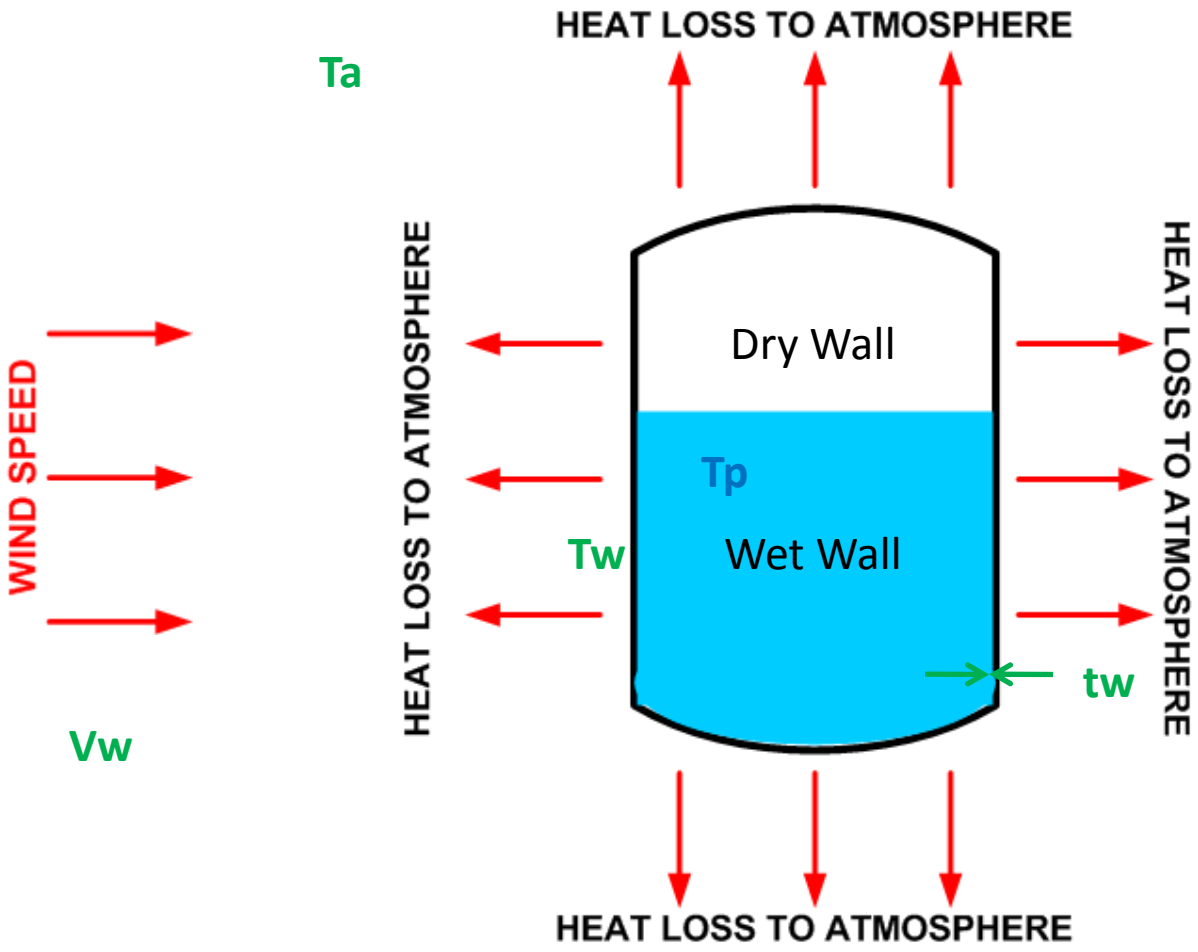
Heat Loss Mechanisms

- **CONDUCTION** – Heat Loss Directly Through Equipment Materials And Materials In Contact With Equipment

- **CONVECTION** – Heat Loss Indirectly Through Fluid Boundary Layer at Equipment Or Insulation Surface

- **RADIATION** – Heat Loss Through Energy Wave Emission At Surface Exposed To Atmosphere

Pressure Vessels

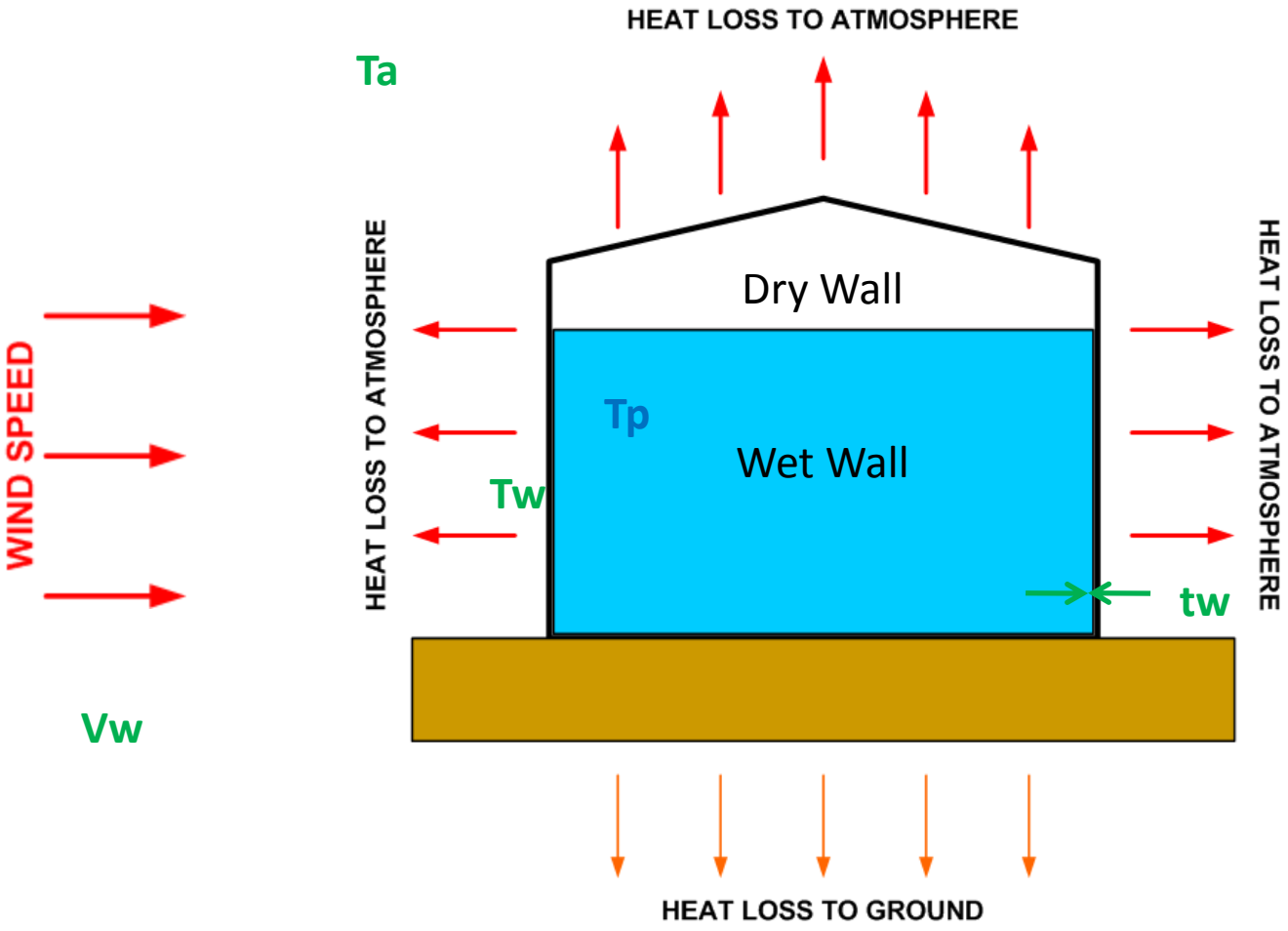


Radiation

Convection

Conduction

Storage Tank

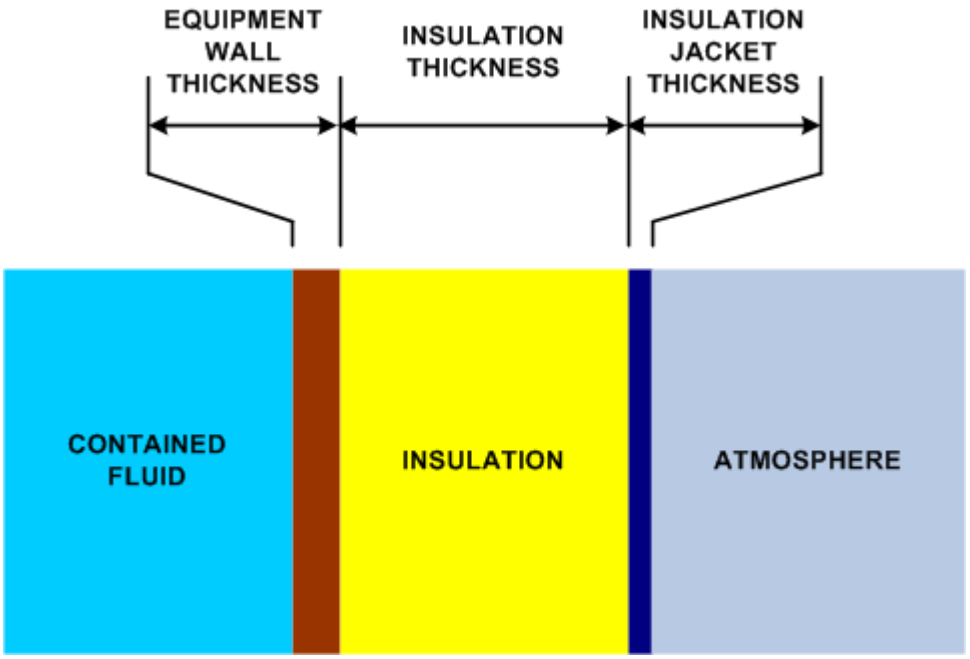


Radiation

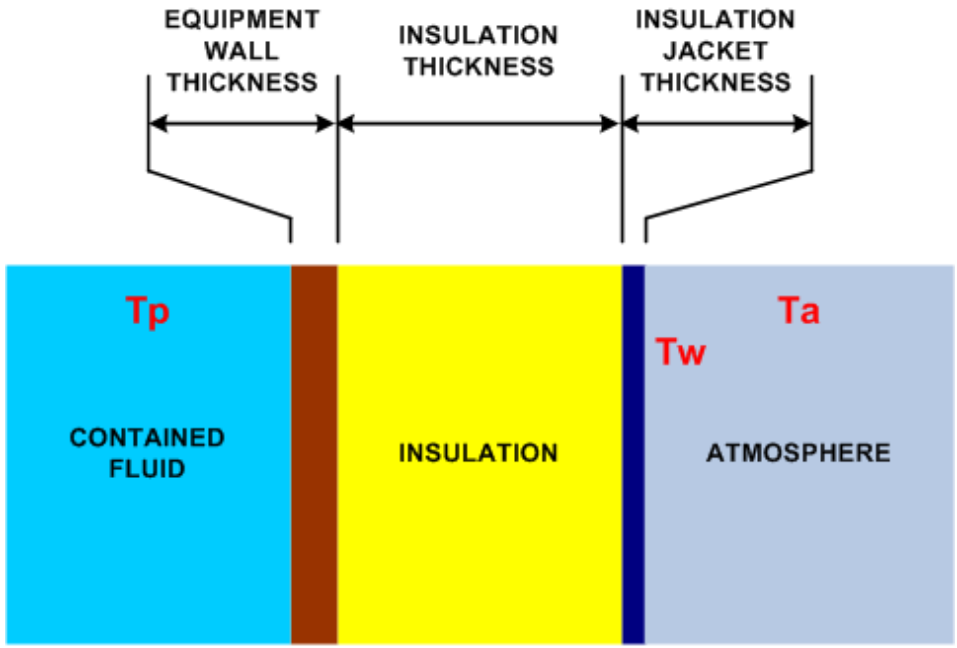
Convection

Conduction

Equipment Heat Loss



Equipment Heat Loss

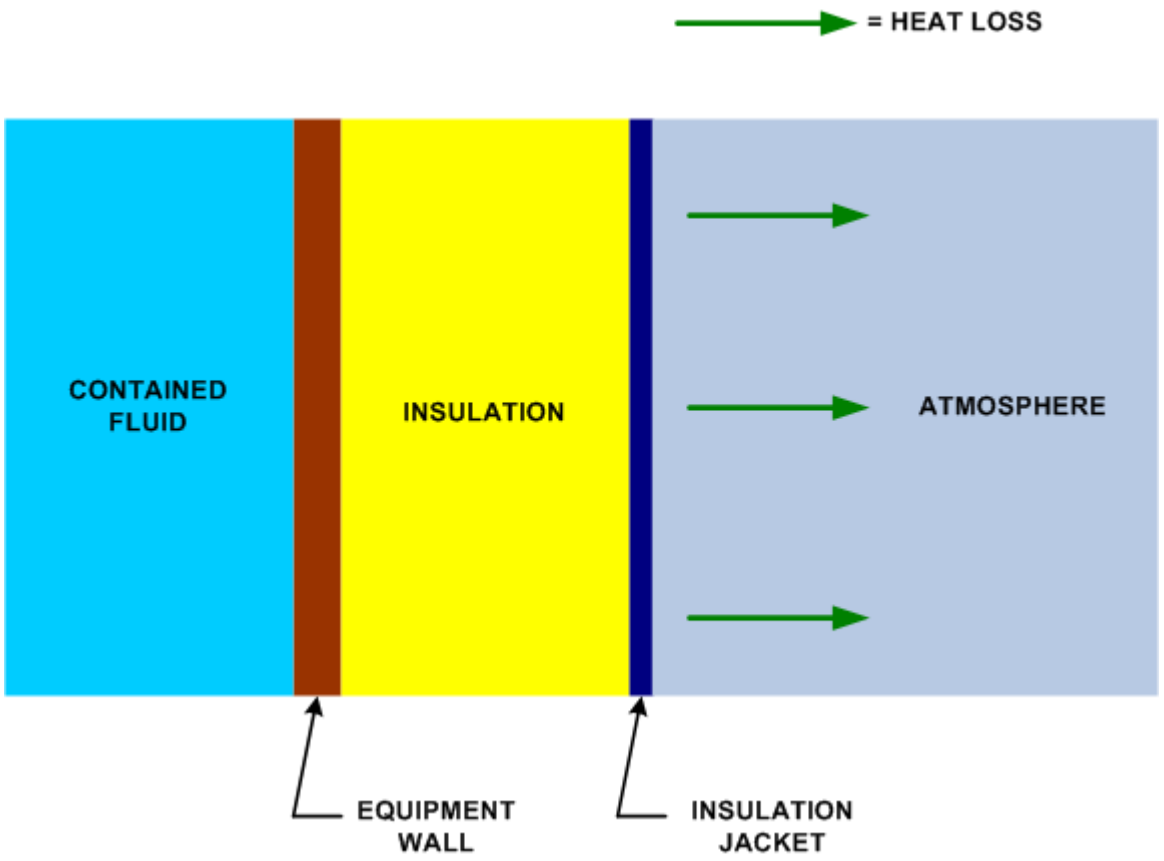


Tp = Process Temperature (ºF)

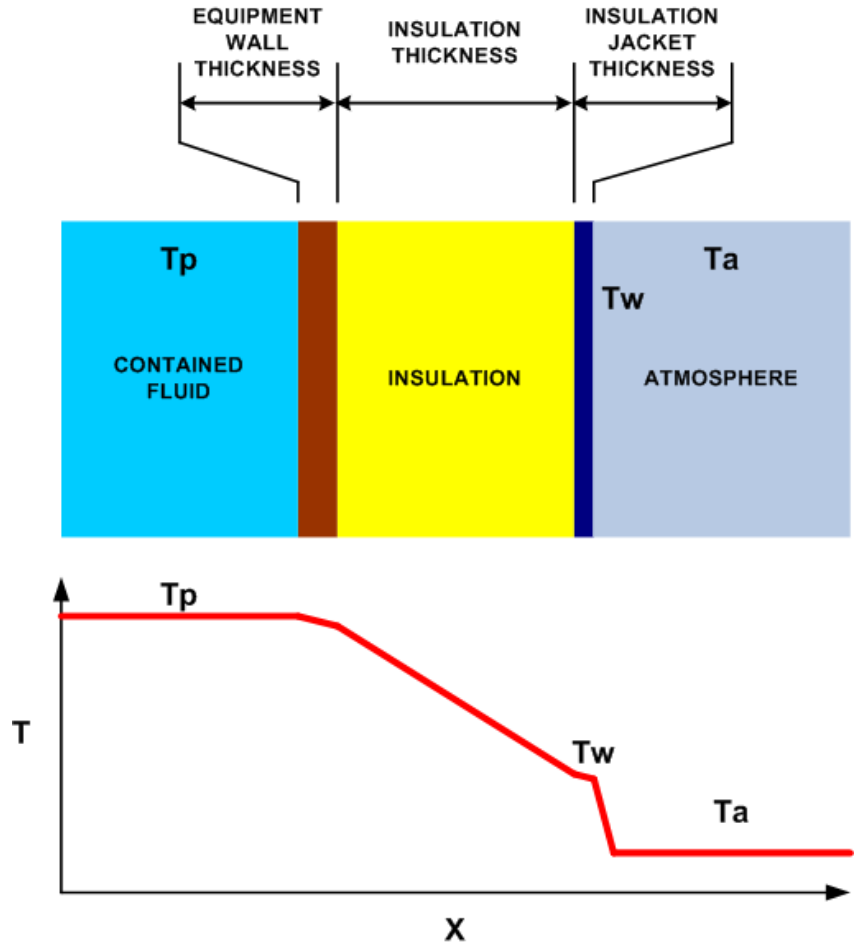
Tw = Surface Temperature (ºF)

Ta = Ambient Temperature (ºF)

Equipment Heat Loss



Equipment Heat Loss

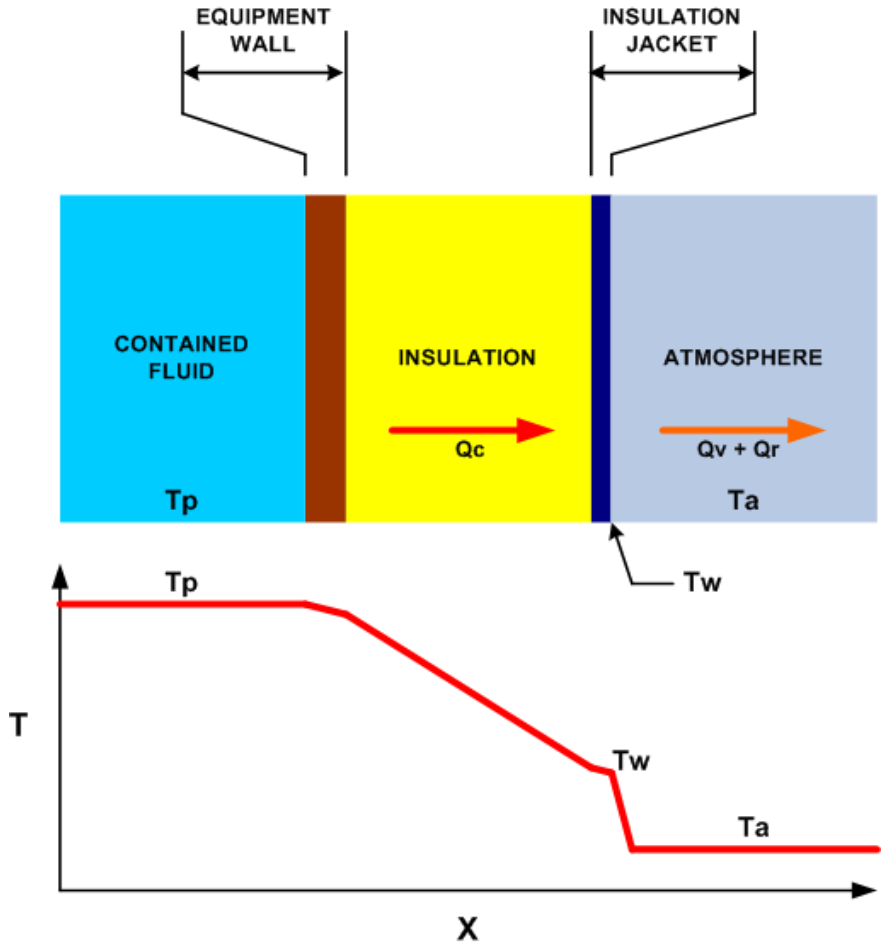


Equipment Heat Loss

Qc = Conduction Heat Transfer (Insulation)

Qv = Convection Heat Transfer (Jacket To Atmosphere)

Qr = Radiation Heat Transfer (Jacket To Atmosphere)



Heat Loss Formula

$$Q = \frac{1}{1/hc + 1/ha} * A * (Tp - Ta)$$

1/hc = Insulation Thickness/ Insulation Thermal Conductivity

Q = Heat Transfer Rate (Btu/hr)

hc = Conduction Heat Transfer Coefficient (Btu/hr/ft^2/ºF)

ha = Atmospheric Heat Transfer Coefficient (Btu/hr/ft^2/ºF)

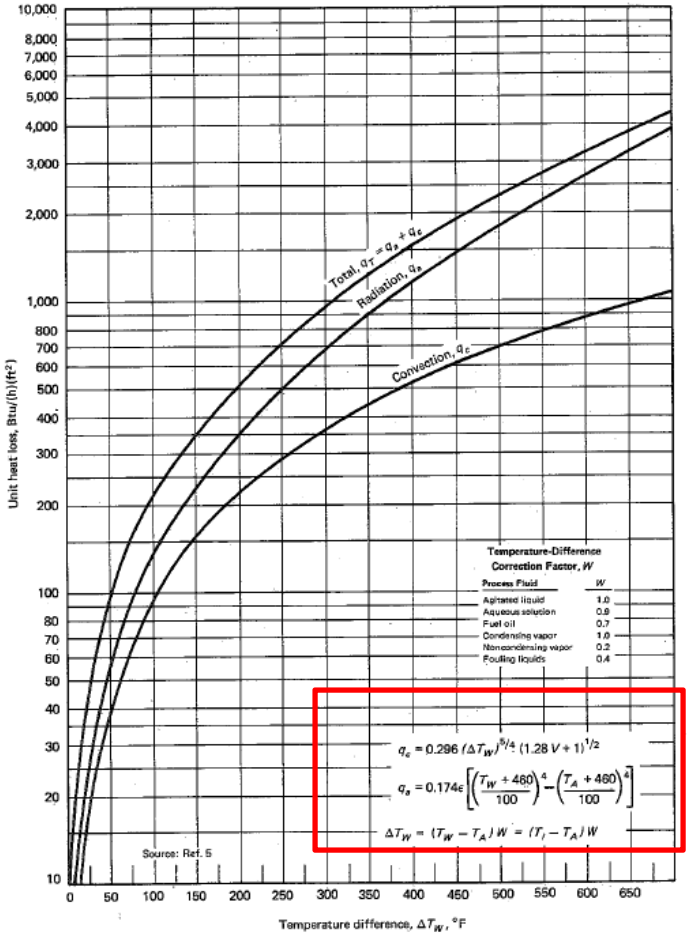
ha = hv + hr = Convection Coefficient + Radiation Coefficient

A = Area (ft^2)

Tp = Process Temperature (ºF)

Ta = Atmospheric Temperature (ºF)

Atmospheric Heat Transfer Coefficient



Insulation Saves Energy – Chemical Engineering, 05/27/74

Atmospheric Coefficient

Convection Coefficient

$$hac = 0.296 * (Tw-Ta)^{1/4} * (1.28 * Vw + 1.0)^{1/2}$$

hac = Convection Coefficient (Btu/hr/ft^2/ºF)

Tw = Surface Temperature (ºF)

Ta = Ambient Temperature (ºF)

Vw = Wind Speed (mph)

Radiation Coefficient

$$har = 0.174 * E * \frac{(Tw'/100)^4 - (Ta'/100)^4}{(Tw-Ta)}$$

har = Radiation Coefficient (Btu/hr/ft^2/ºF)

E = Emissivity

Tw' = Surface Absolute Temperature (ºR)

Ta' = Ambient Absolute Temperature (ºR)

Tw = Surface Temperature (ºF)

Ta = Ambient Temperature (ºF)

Atmospheric Coefficient

$$ha = hac + har$$

ha = Atmospheric Coefficient (Btu/hr/ft^2/ºF)

hac = Convection Coefficient (Btu/hr/ft^2/ºF)

har = Radiation Coefficient (Btu/hr/ft^2/ºF)

Convection

Wind Speed mph	Surface Temperature °F	Ambient Temperature °F	hac Btu/hr/ft^2/ºF
0	100	20	0.89
0	200	20	1.1
10	100	20	3.3
10	200	20	4.0
20	100	20	**4.6**
20	200	20	**5.6**
30	150	20	6.3
40	150	20	7.2

Radiation

Emissivity	Surface Temperature °F	Ambient Temperature °F	har Btu/hr/ft²/ºF
0.50	100	20	0.49
0.50	200	20	0.66
0.70	100	20	0.69
0.70	200	20	0.92
0.90	100	20	**0.89**
0.90	200	20	**1.2**
1.0	100	20	0.98
1.0	200	20	1.3

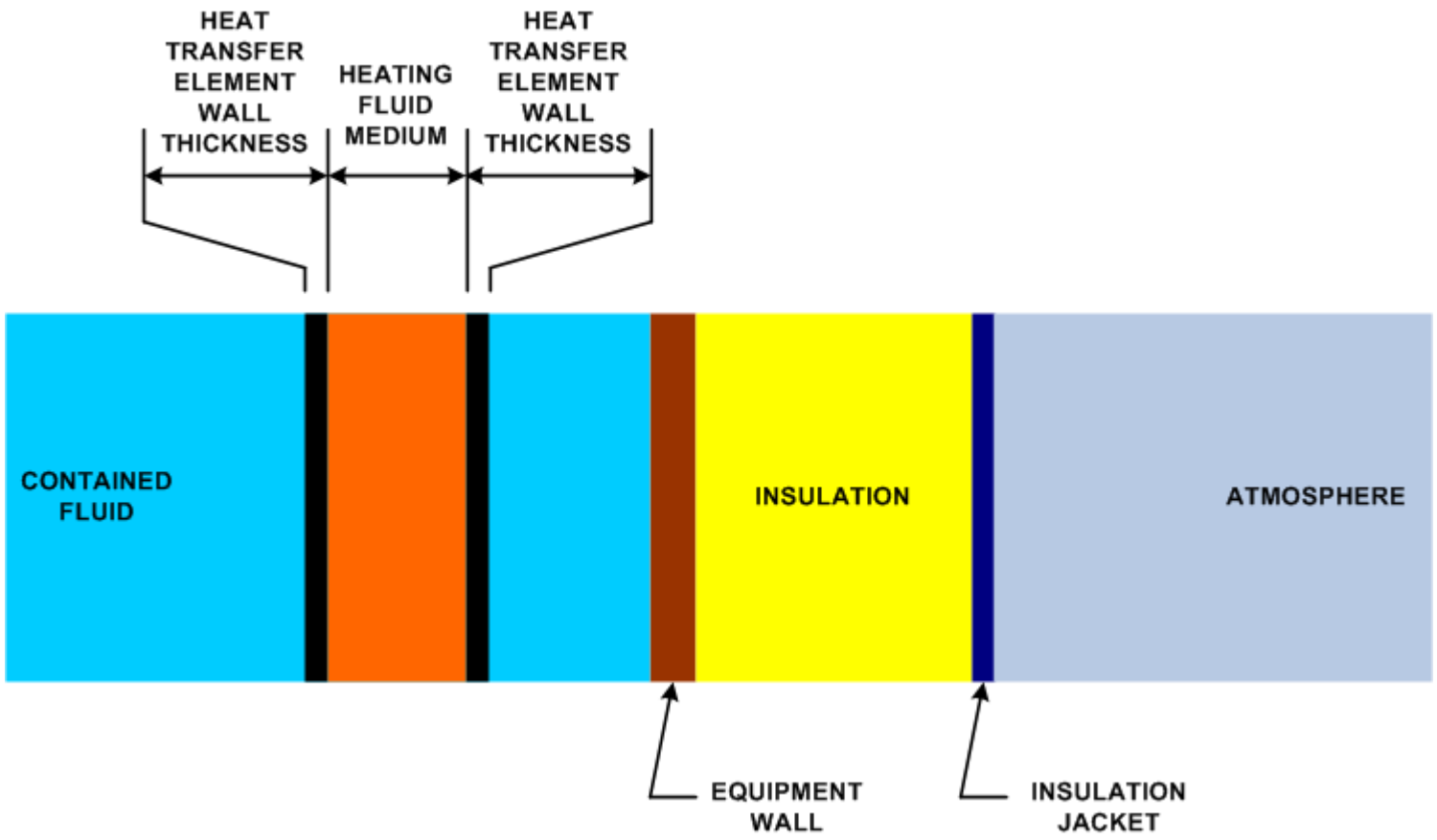
Equipment
Heat Gain

Heat Gain Mechanisms

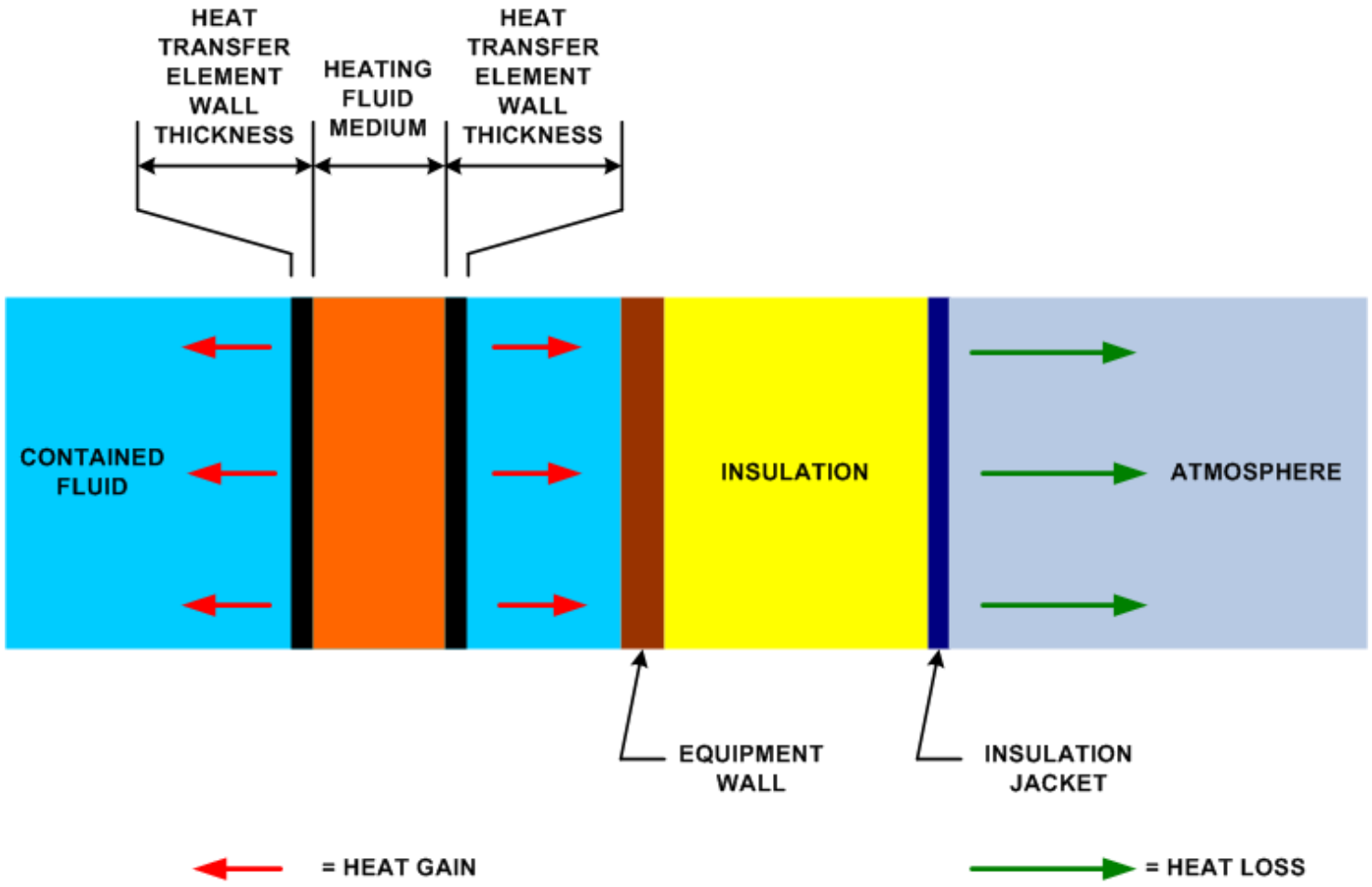
- **CONDUCTION** – Heat Transfer To Equipment Through Equipment Materials And Materials In Contact With Equipment

- **CONVECTION** – Heat Transfer At Fluid Boundary Layers Inside And Outside Of Equipment And Heat Exchange Attachments In Contact With Equipment

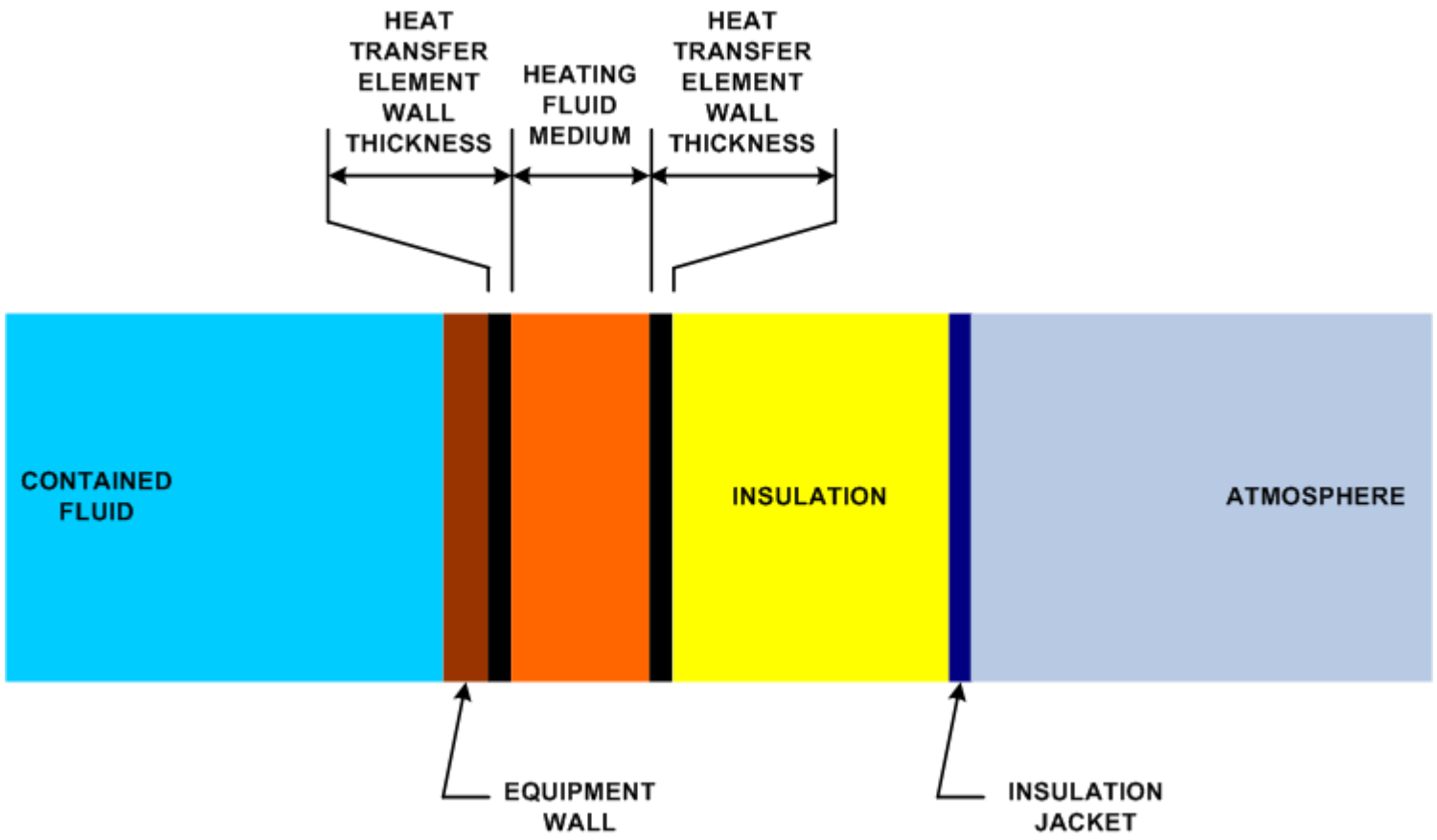
Internal Element



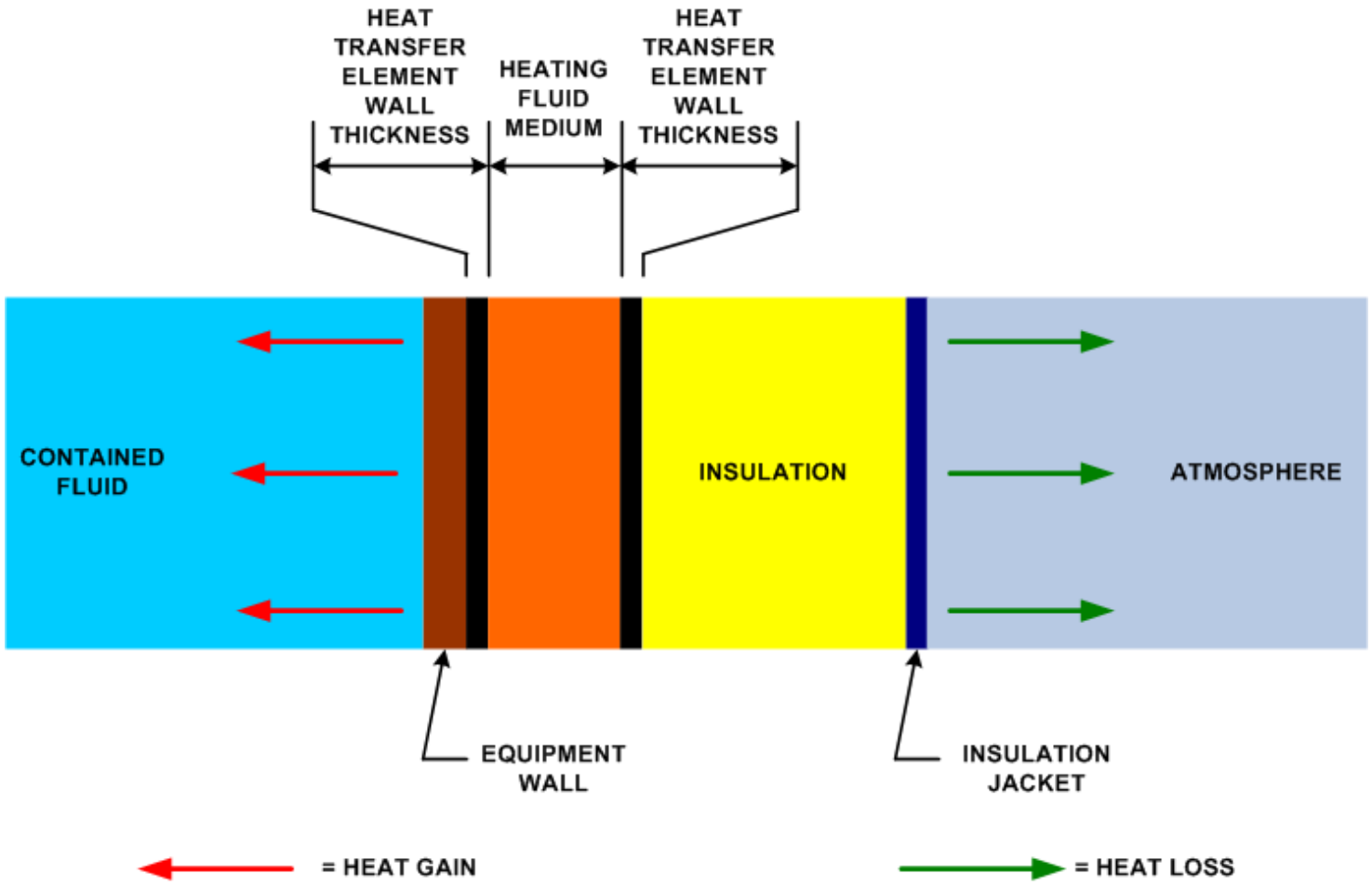
Internal Element



External Element



External Element



Equipment Heat Transfer

- Temperature Maintenance

Heat Gain = Heat Loss

- Process Heat Transfer

Heat Gain > Heat Loss

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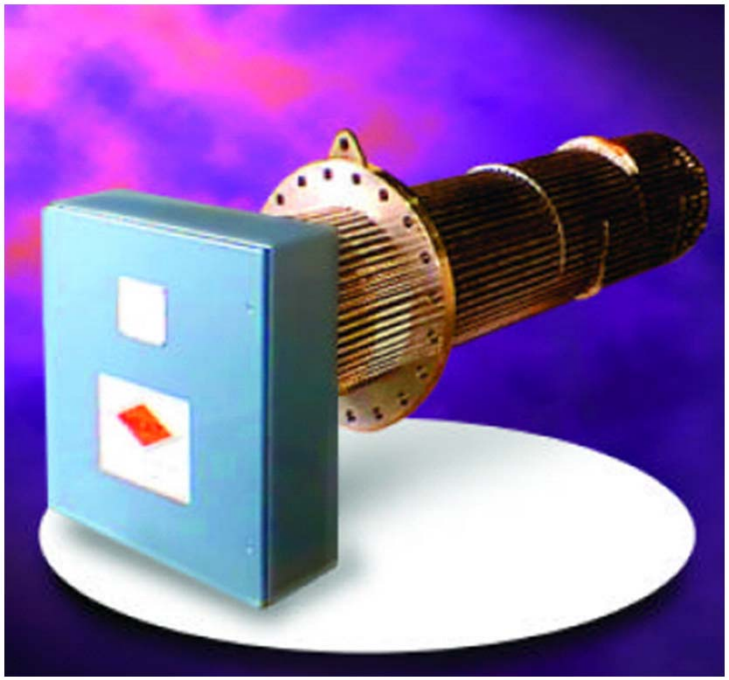
Equipment
Heat Transfer
Attachments

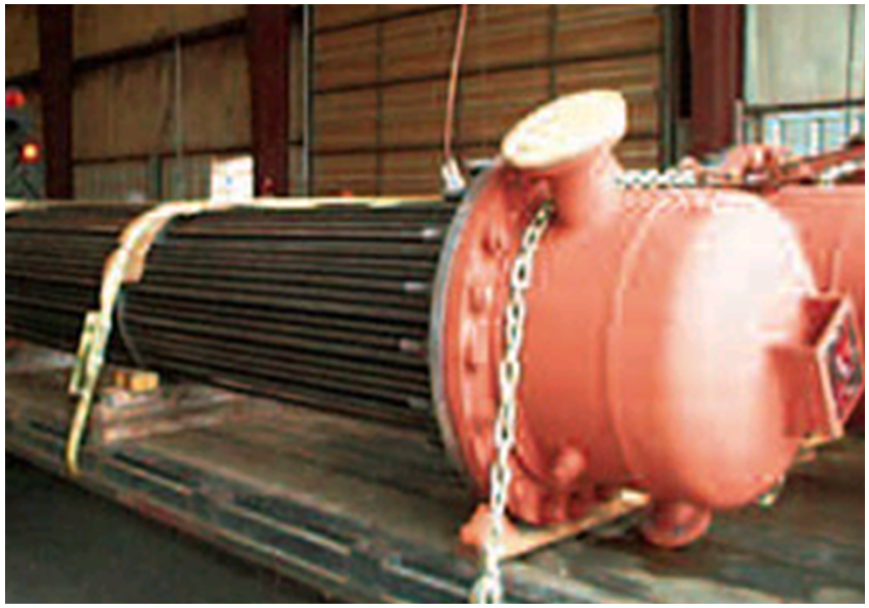
Heat Transfer Attachments

Option		Internal	External	Attached	Integral
Heat Exchange Insert	Bayonet Exchanger Pipe Coil Mixing Eductor Sparger	X			X
Jacket	Full Half Pipe		X		X
Tracers	Electric Pipe Tubing ControTrace		X	X	
Plate Coil			X	X	

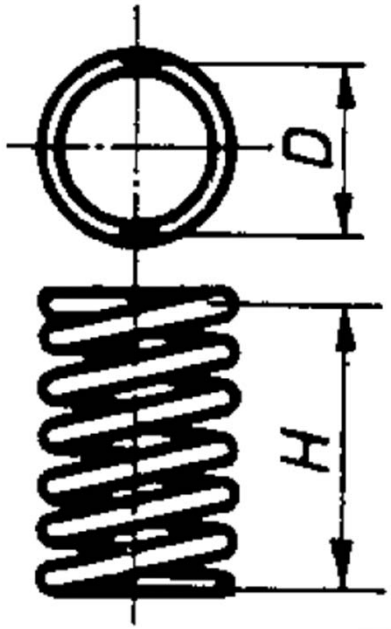
Internal – Electric Bayonet

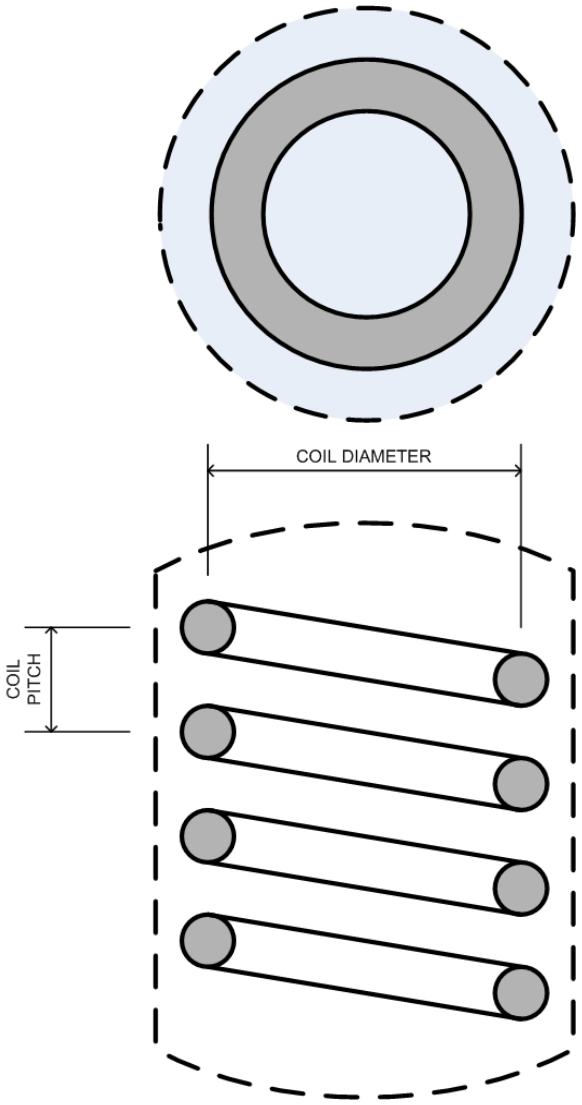


Internal – Tube Bundle



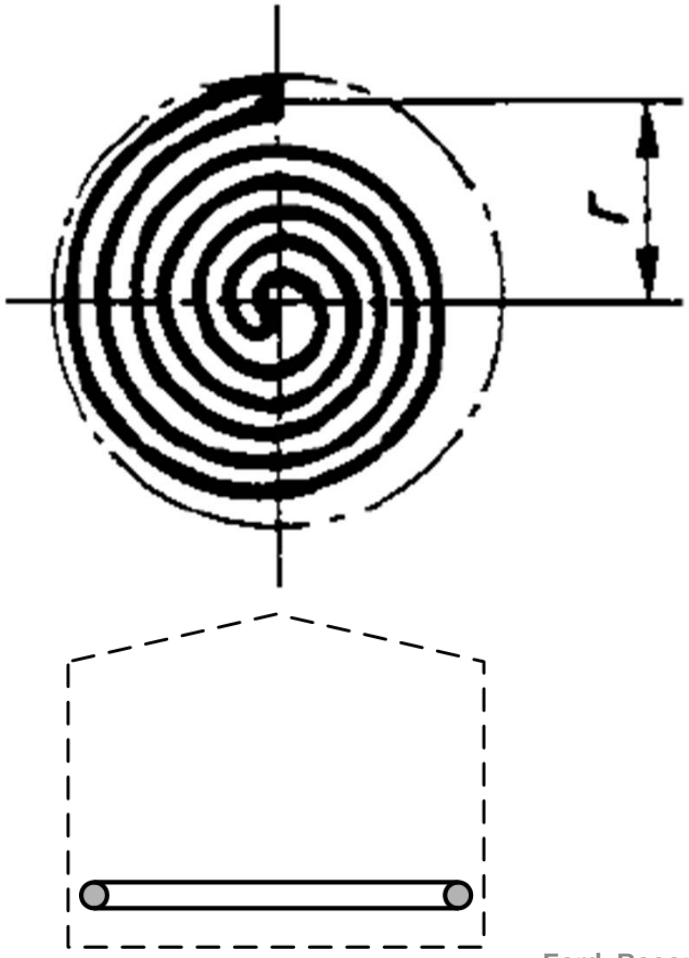
Internal - Helical Coil



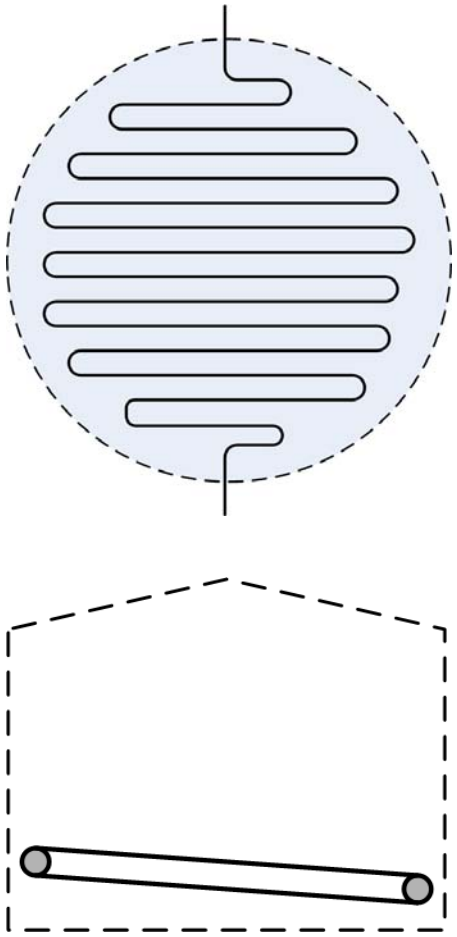


Internal – Flat Coil

Spiral



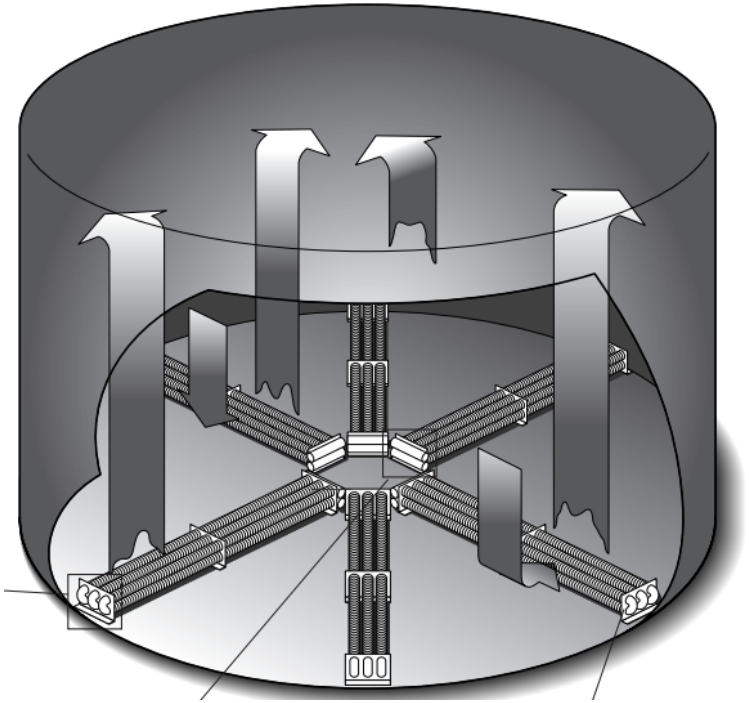
Serpentine



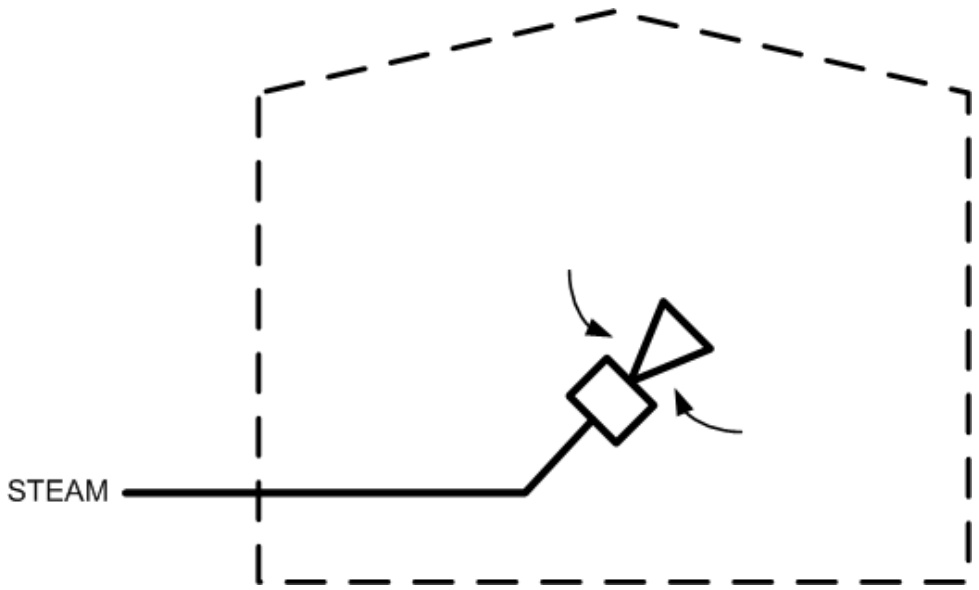
Internal - Koch

Koch TF

Armstrong BHC/BHS

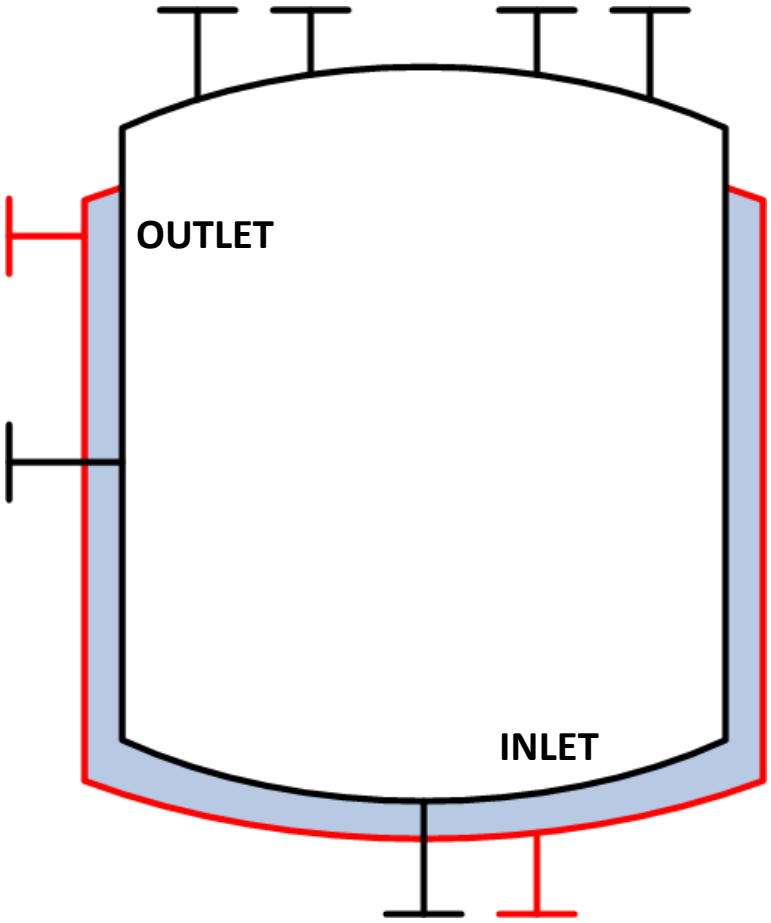


Internal – Mixing Eductor

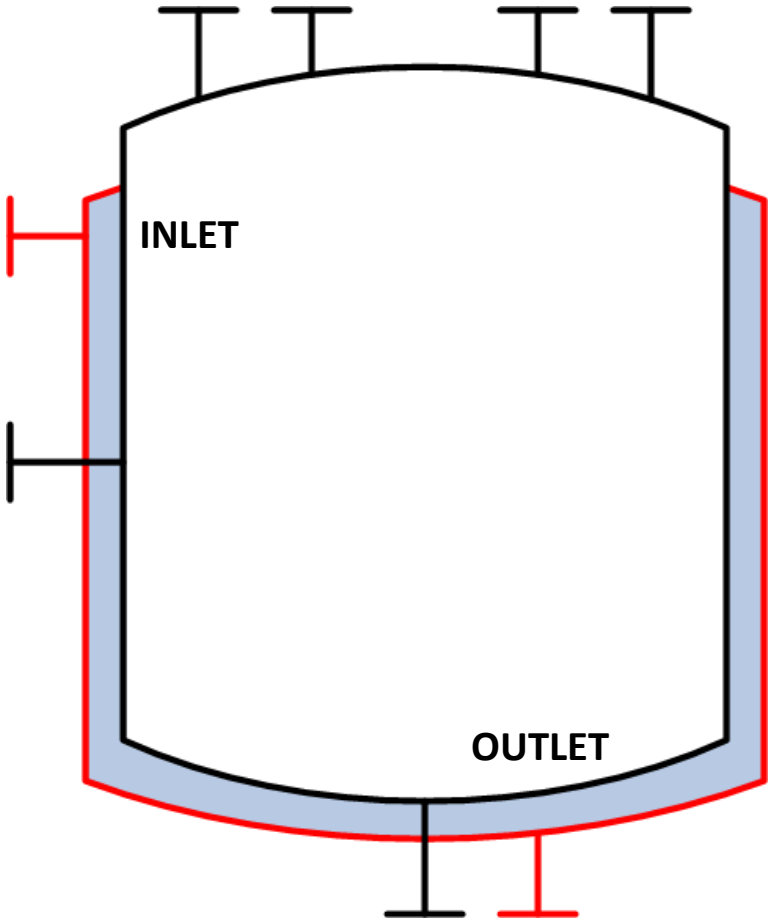


External – Full Jacket

Liquid Service

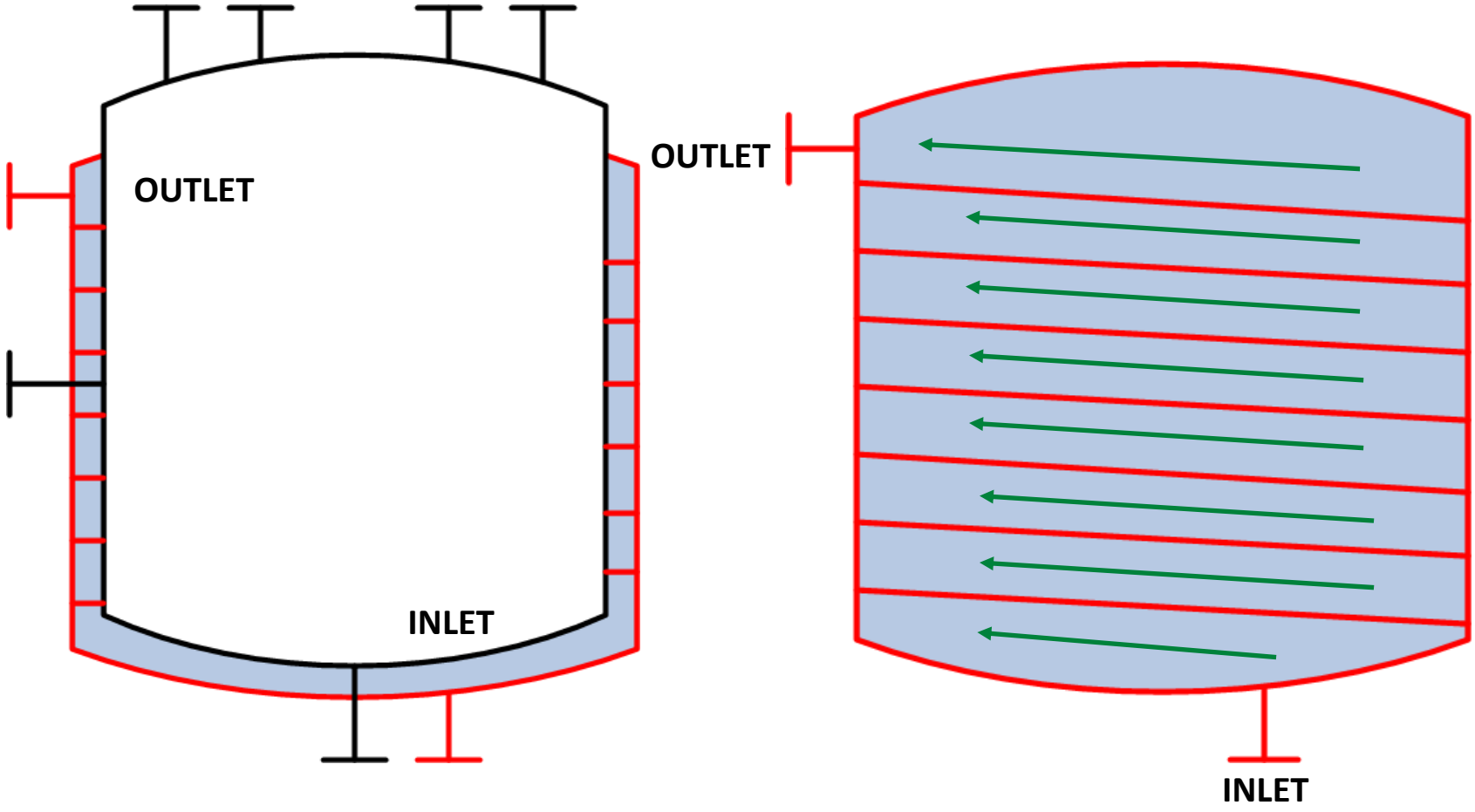


Steam Service



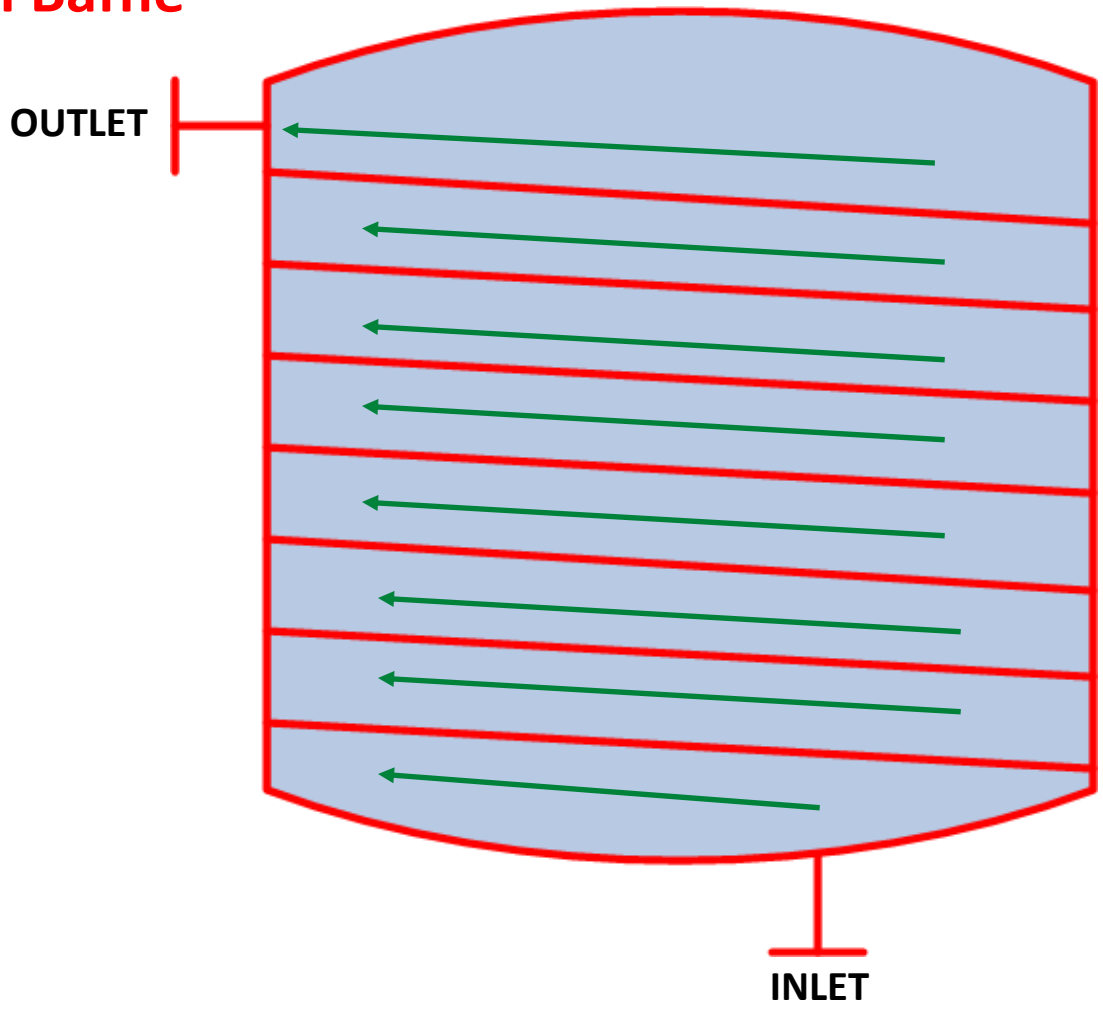
External – Full Jacket

Spiral Baffle



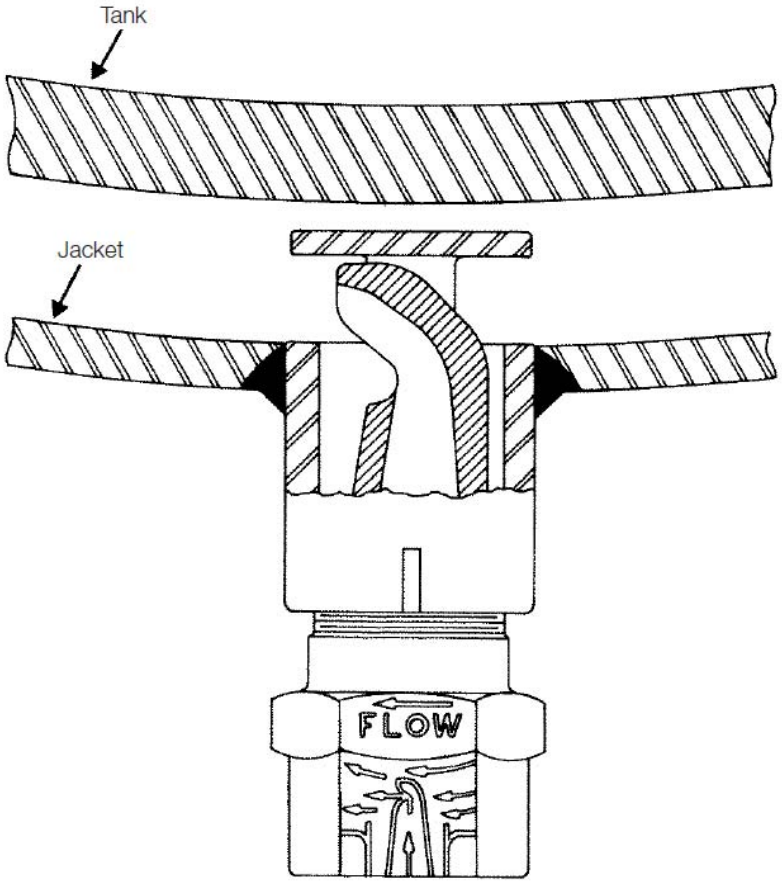
External – Full Jacket

Spiral Baffle



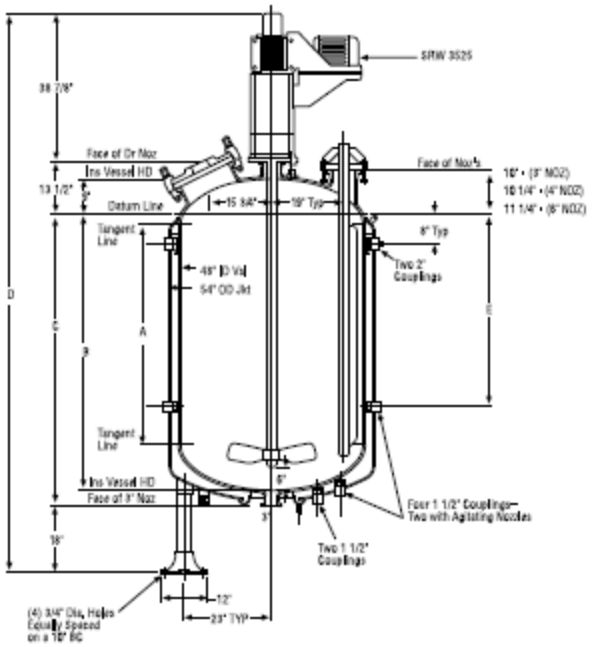
External – Full Jacket

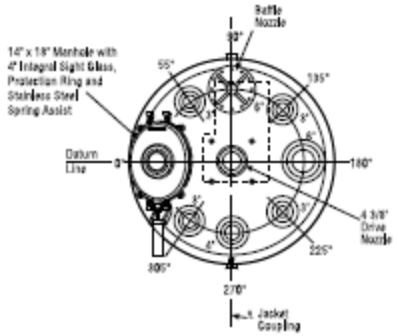
Pfaudler Agitating Nozzle

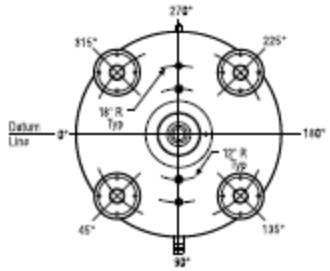


External – Full Jacket

Pfaudler RS-48







HT Fluid: Water

Nozzles Required: 2

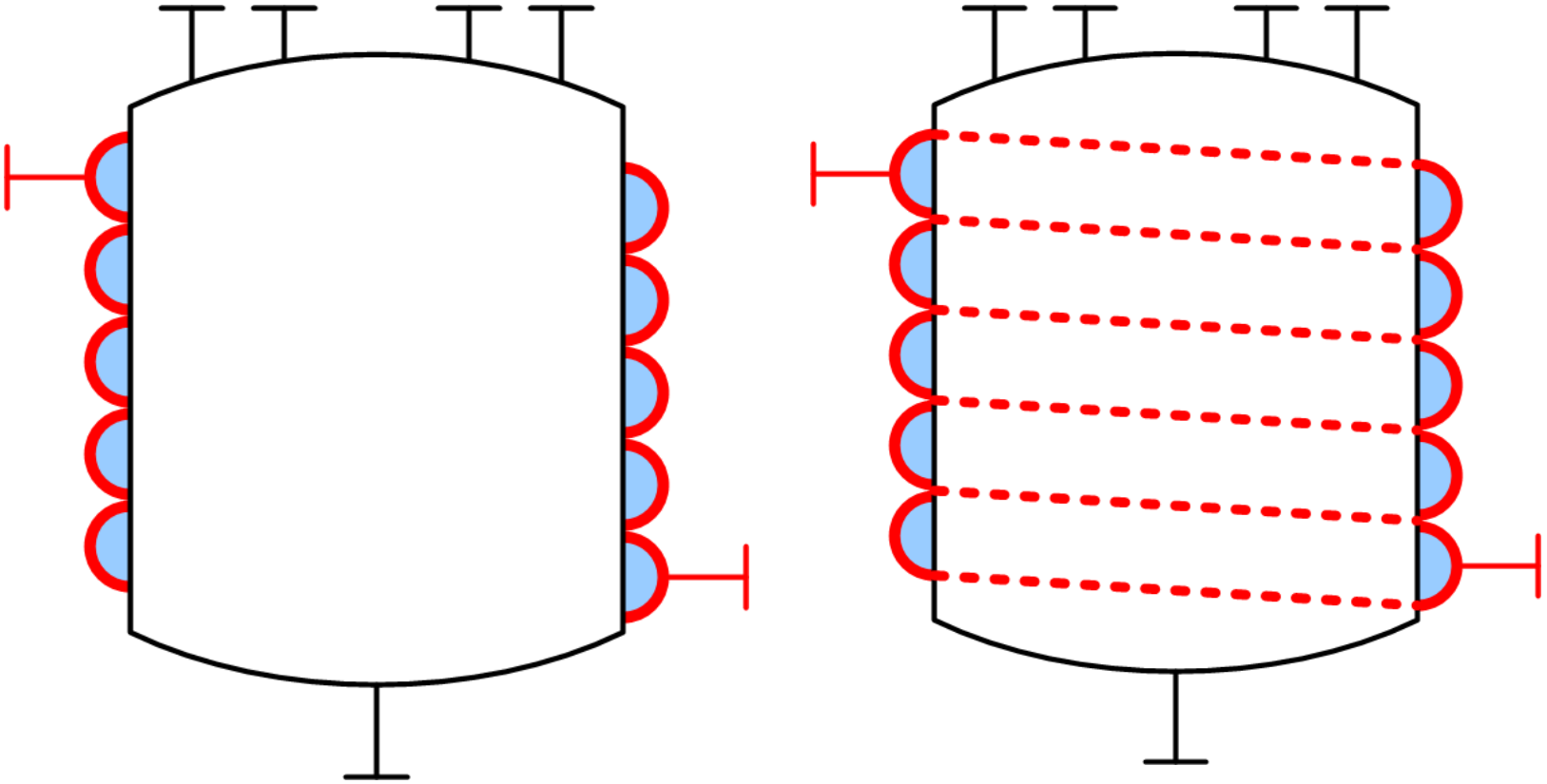
Nozzle Size: 1.5 in.

dP: 20 psi

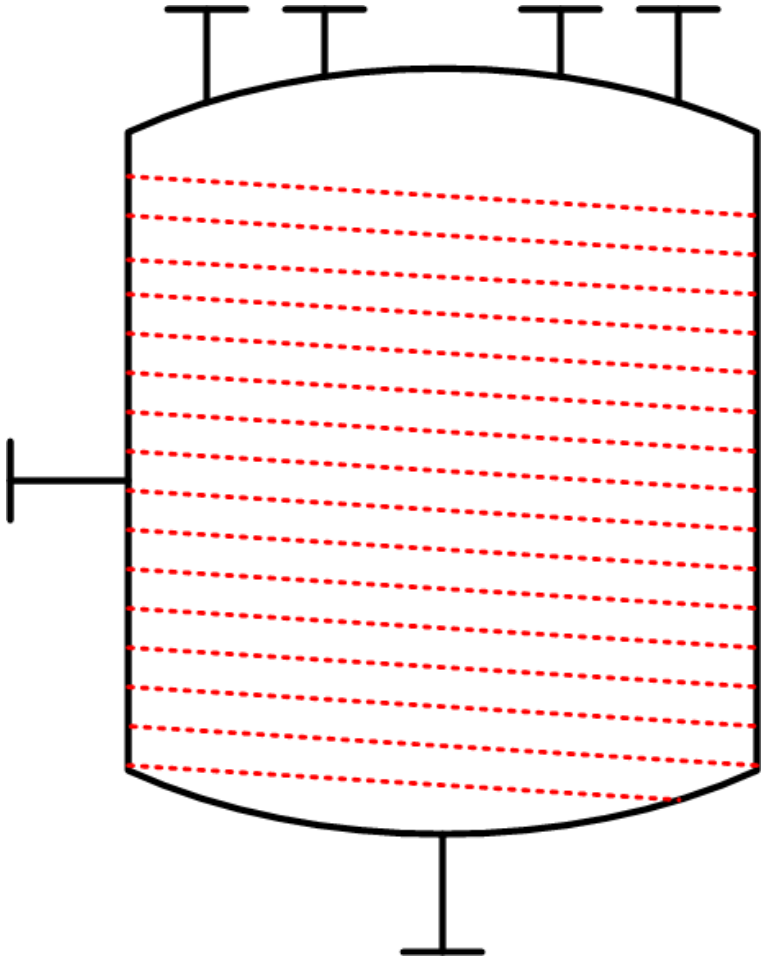
Total Flow: 68 gpm

hj = 548 Btu/hr-ft^2-^{o}F

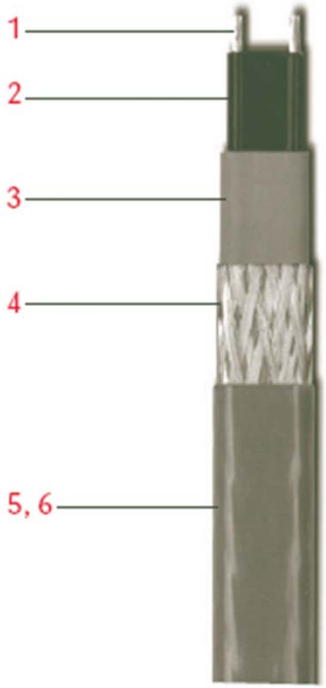
External – Half Pipe Jacket



External - Electric Tracer



Thermon BSX



Construction . . .

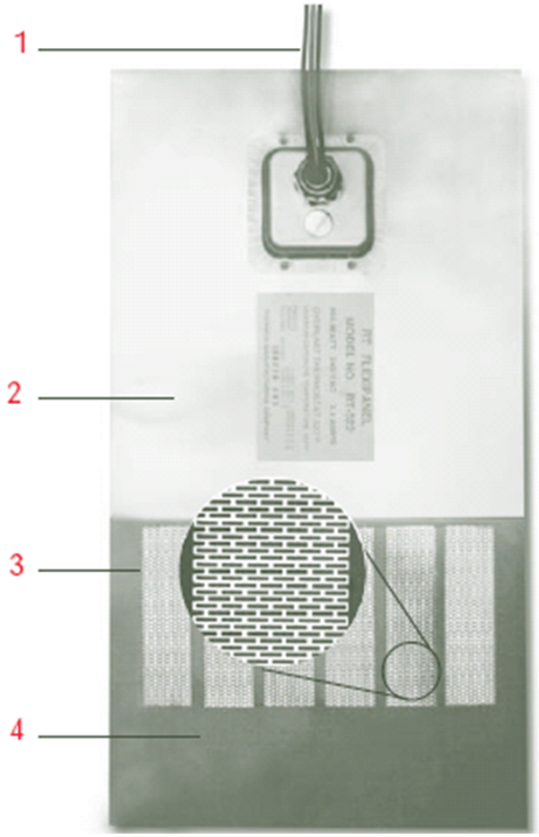
1 Nickel-Plated Copper Bus Wires (16 AWG)
2 Radiation Cross-Linked Semiconductive Heating Matrix
3 Radiation Cross-Linked Dielectric Insulation
4 Tinned Copper Braid
5 Polyolefin overjacket provides additional protection to cable and braid where exposure to aqueous inorganic chemicals is expected.

Options . . .

6 FOJ Fluoropolymer overjacket over tinned copper braid provides additional protection to cable and braid where exposure to organic chemicals or corrosives is expected.

External - Electric Panel

Thermon RT Flexipanel



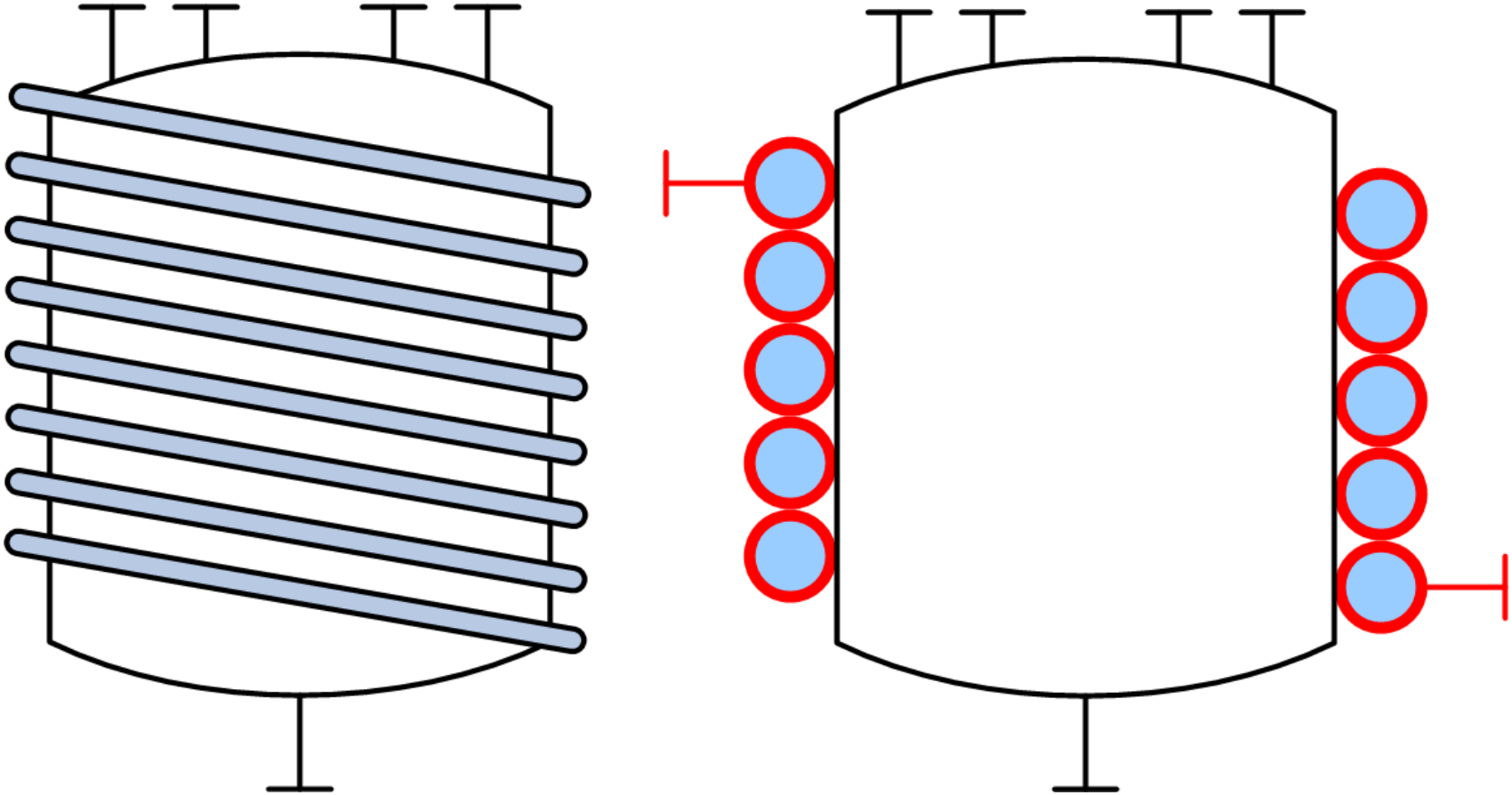
Construction[3] . . .

1 High Temperature Lead Wires (16 AWG)
2 Protective Metal Jacket
3 Parallel Circuit High Temperature Alloy Heating Element
4 Heat-Laminated, High Temperature Silicone Rubber Insulation

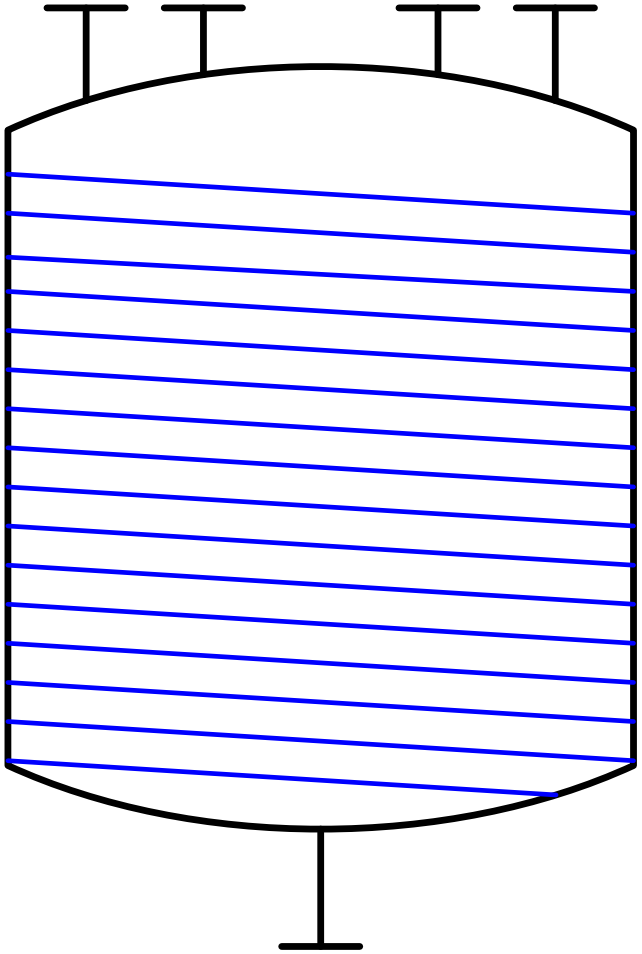
Electric Tracers / Panels

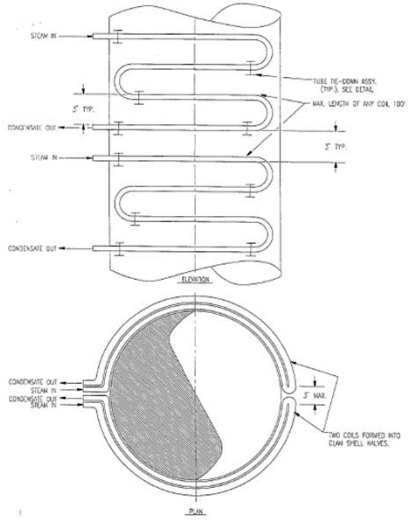
- Heat Duty In Watts Per Foot For Cable Or Watts Per Square Inch For Panels
- Self-Regulating Feature Available
- For Offsite Location, Electricity May Be More Available Than Other Energy Sources
- Remote Monitoring And Control Possible

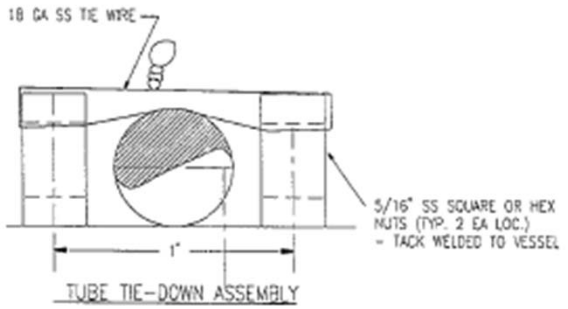
External - Pipe Tracer

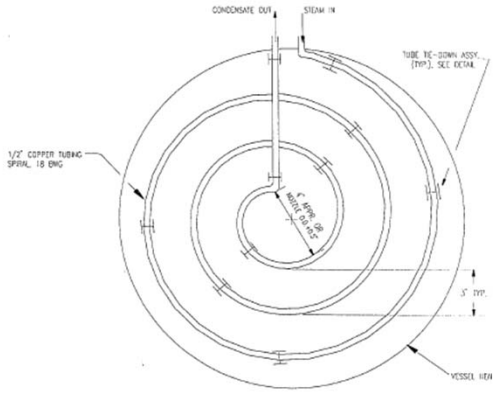


External - Tubing Tracer





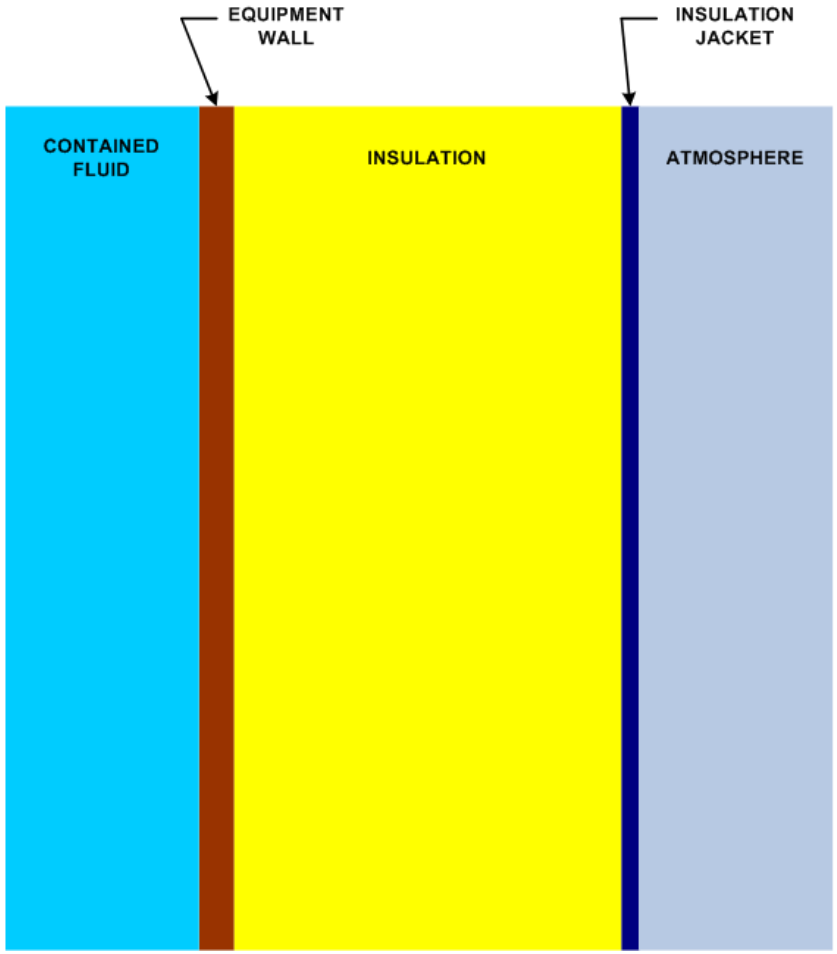




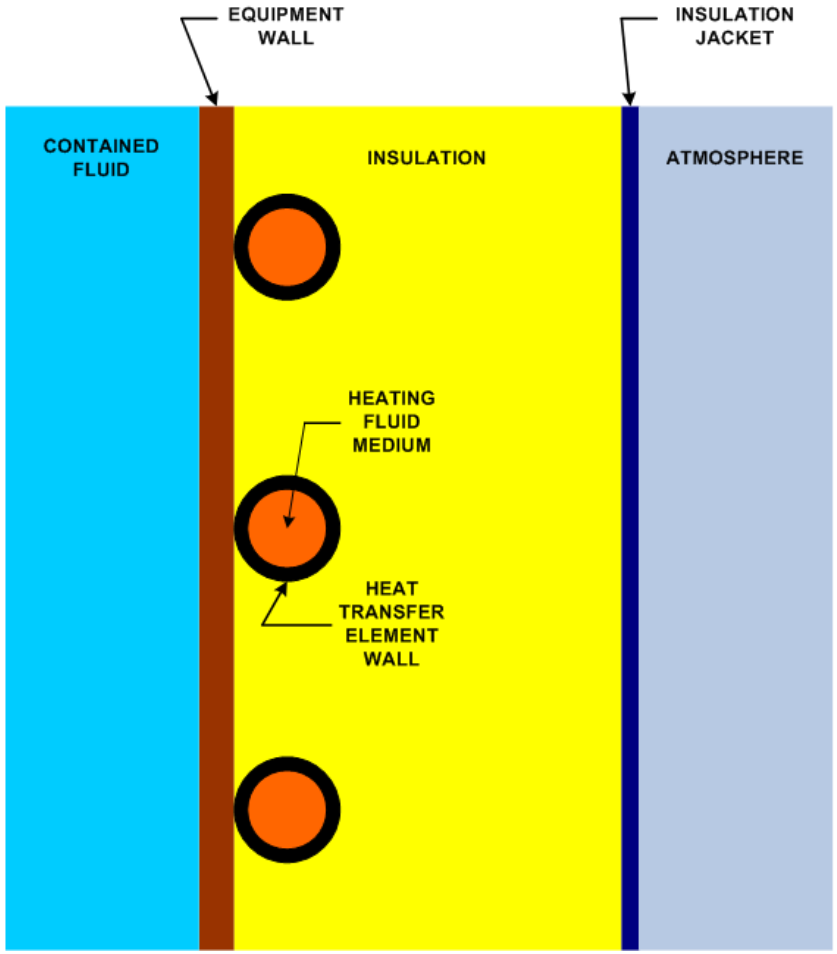
Pipe / Tubing Tracers

- Tubing Is Easier To Bend To Follow Equipment Contours Particularly Heads and Nozzles
- Selection of Pitch (Distance Between Runs) Is Critical To Ensure Wall Temperature Stays Above **Minimum Maintain Temperature**
- Design Of Tubing Heat Tracing Is Typically The Engineering Contractor Responsibility

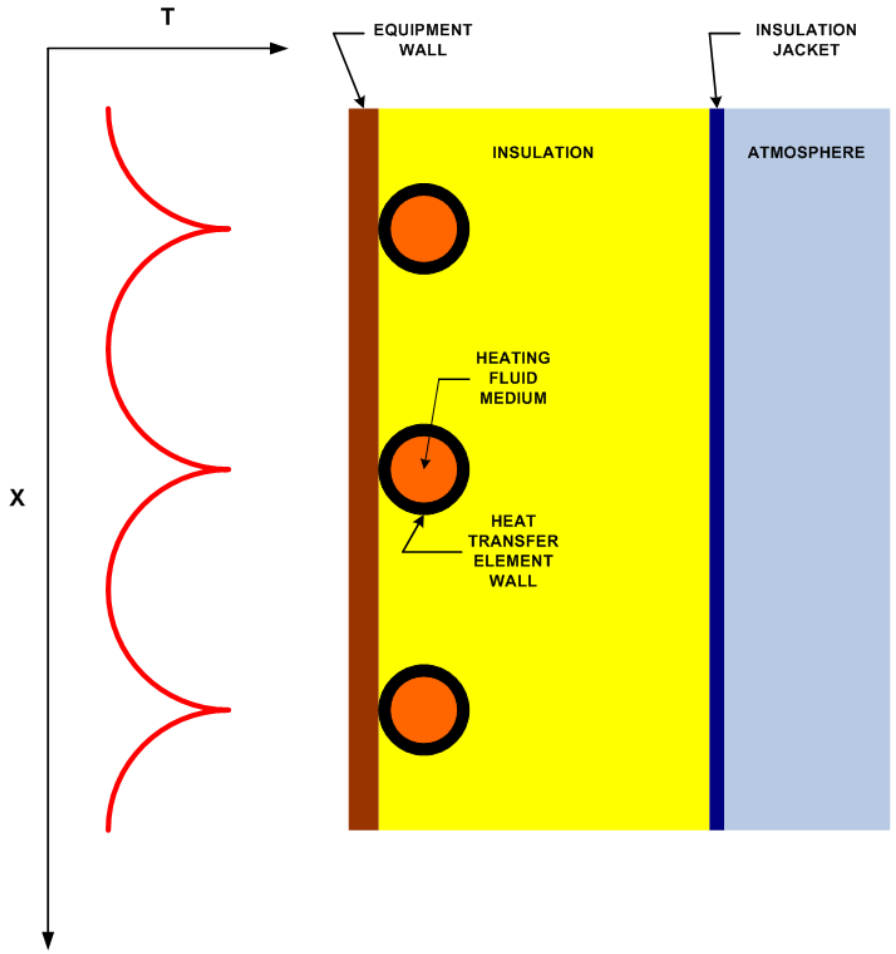
Pipe / Tubing Tracers



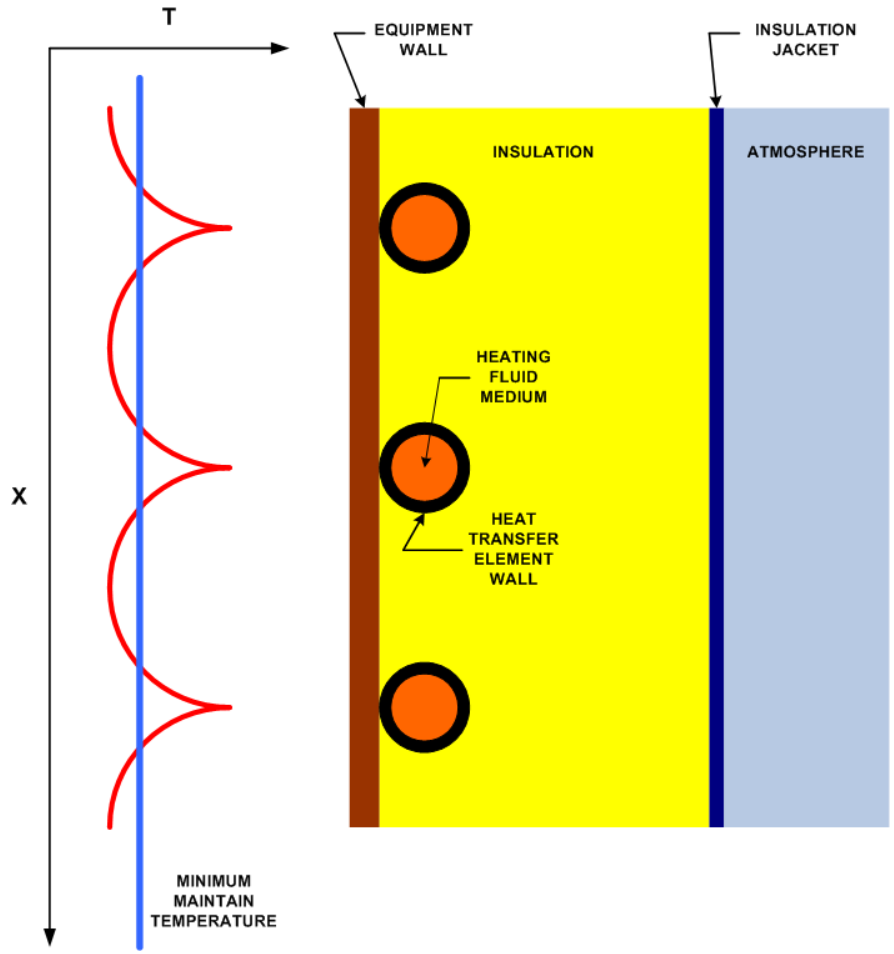
Pipe / Tubing Tracers



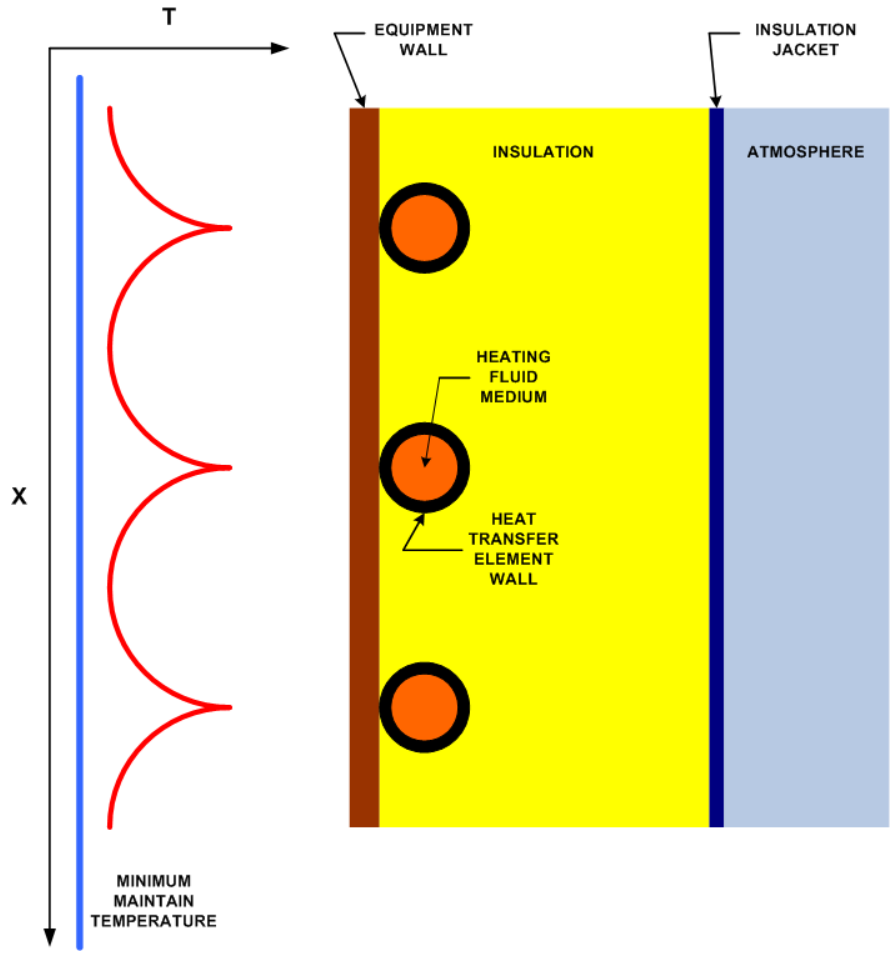
Pipe / Tubing Tracers



Pipe / Tubing Tracers

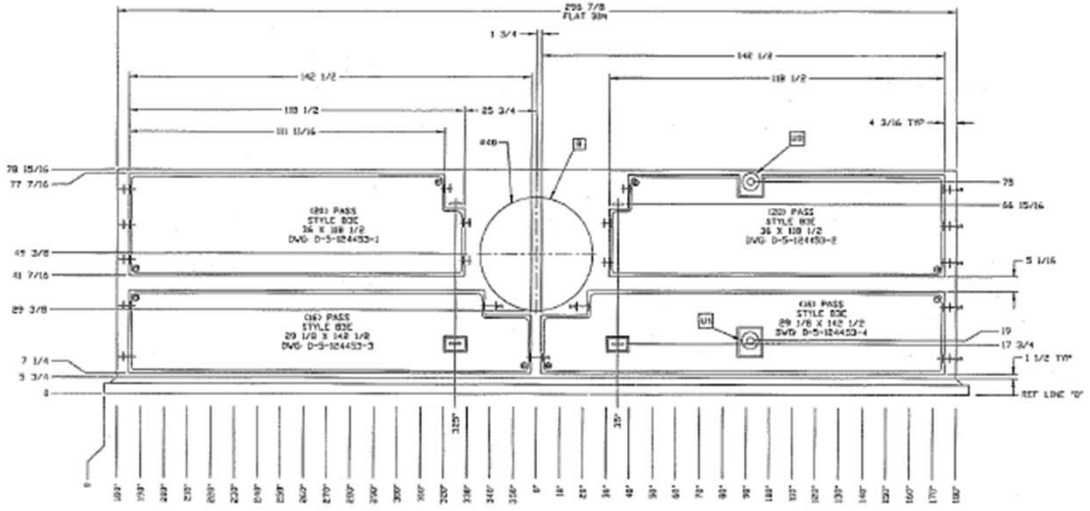


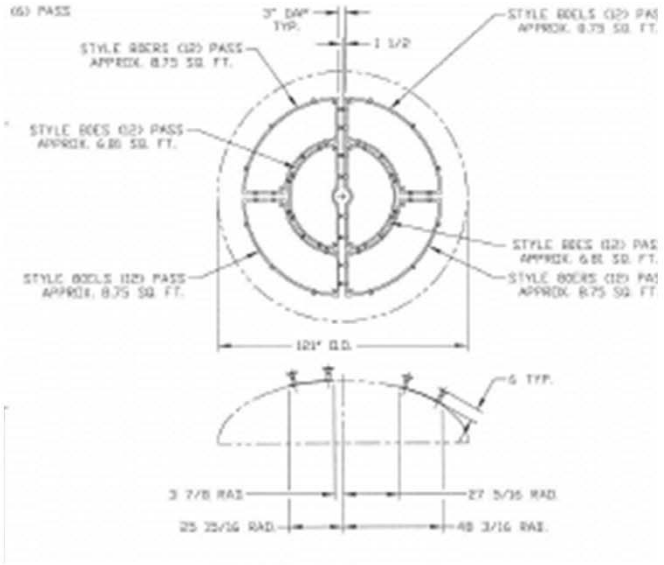
Pipe / Tubing Tracers



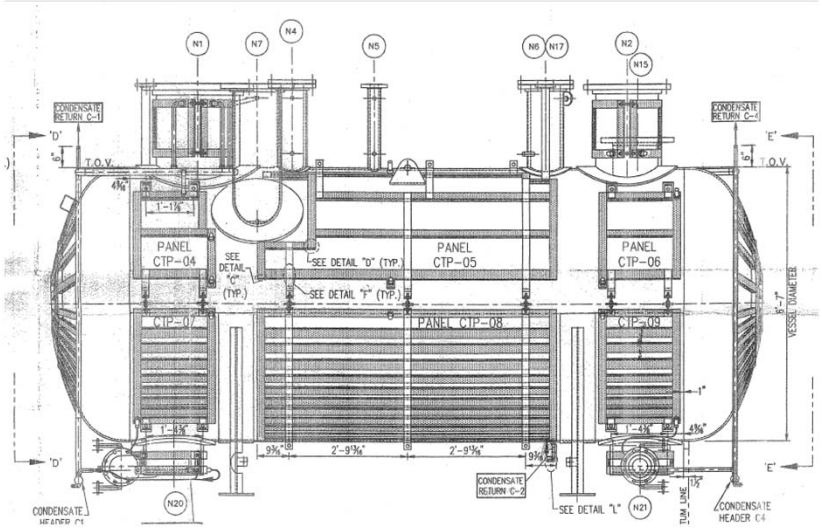
External - Plate Coil

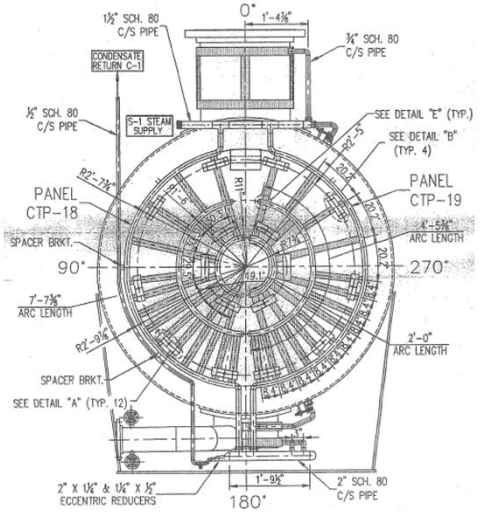
Tranter





External - ControTrace





Clamp-On Jacket

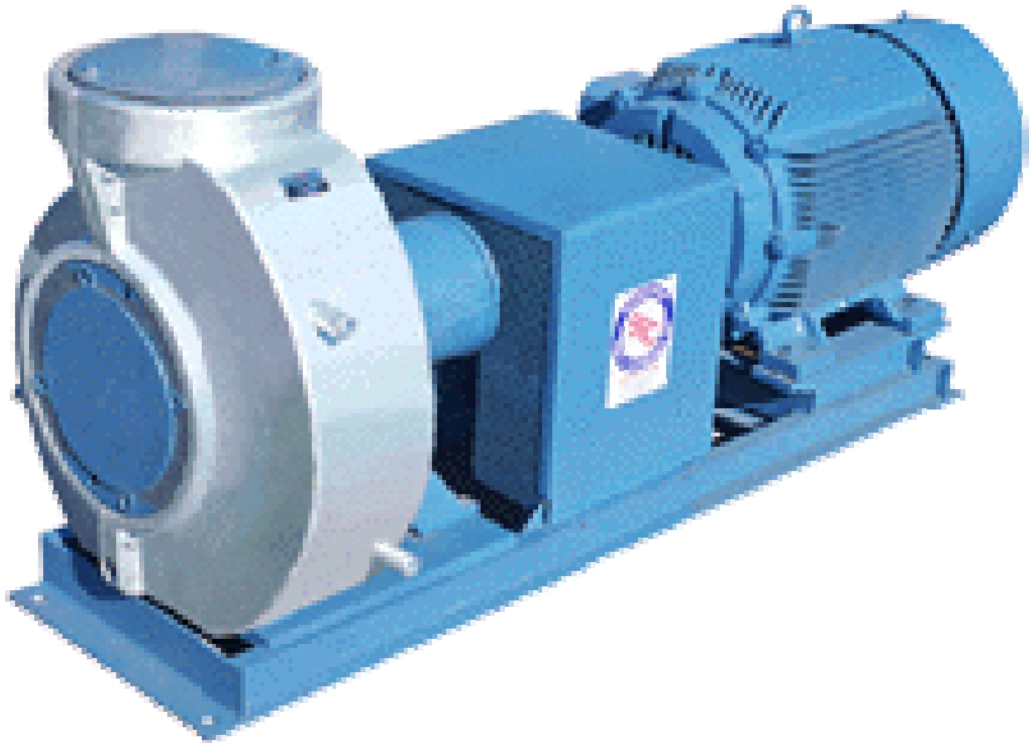


Plate Coil Vs Tracers

- Manufactured Assembly Takes Less Labor To Install Than Pipe Or Tubing Tracers
- Tubing Tracer Installed At Fabricator May Be Damaged During Shipping – Coil Assembly Is Typically More Rugged Design
- Heat Transfer Design Is Typically Coil Assembly Vendor Responsibility

Summary

- **Understand Process Objective**:
  - Temperature Maintenance
  - Process Heat Transfer
- **Selection Of Heat Transfer Components For Equipment Should Be Based On:**
  - Level Of Heat Transfer Requirement
  - Process Considerations
  - Cost